<u>**TITLE**</u>

APPARATUS FOR PRODUCING REAL-TIME ANAGLYPHS

<u>**FIELD OF THE INVENTION**</u>

The present invention relates generally to the field of three-dimensional (3D) computer graphics and, in particular, to an apparatus for producing real-time anaglyphs that create the perception of depth when viewed through anaglyph spectacles.

<u>**BACKGROUND OF THE INVENTION**</u>

A problem with computer systems for generating images is their need to emulate natural 3D images compared to images that lack realism due to the absence of depth cues. Many techniques have been devised and developed for producing stereoscopic images to achieve 3D effect. One technique is to provide left and right eye images for a single two-dimensional image and displaying them alternately. A viewer is provided with liquid crystal shuttered spectacles to view the left and the right eye images. The shuttered spectacles are synchronized with the display signal to admit one eye at a time to view the proper image. More specifically, the liquid crystal shutter for the right eye is opened when the right eye image is displayed and the liquid crystal shutter for the left eye is opened when the left eye image is displayed. In this way, the observer's brain merges or fuses the left and right eye images to create the perception of depth. The amount of offset between the elements of left

and right eye images determines the depth at which the elements are perceived in the resulting stereo image. Another technique for providing stereoscopic view is the use of anaglyph. An anaglyph is an image generally consisting of two distinctly colored, and preferably, complementary colored, images. Theory of anaglyph is the same as the technique described above - the observer is provided with separate left and right eye images and the horizontal offset in the images provides the illusion of depth. The observer views the anaglyph consisting of two images of the same object in two different colors, such as red and blue-green, and shifted horizontally. The observer wearing anaglyph spectacles views the images through lenses of matching colors. In this manner, the observer sees, for example, only the blue-green tinted image with the blue-green lens, and only the red tinted image with the red lens, thus providing separate images to each eye. The advantages of this implementation are that the cost of anaglyph spectacles is lower than that of liquid crystal shuttered spectacles and there is no need for providing an external signal to synchronize the anaglyph spectacles.

SUMMARY OF THE INVENTION

It is one object of the present invention to provide an apparatus for producing a real-time anaglyph in a personal computer.

It is another object of the present invention to provide an apparatus employing animation pictures generated from a 3D graphics accelerator used in a

personal computer to create real-time stereoscopic images.

The present invention is an apparatus for producing a real-time anaglyph. The disclosed apparatus comprises a graphics engine, a memory and an anaglyph generator. The graphics engine provides a sync signal and generates a left eye image and a right eye image in accordance with a horizontal offset calculated from 3D graphic animation, in which the horizontal offset between the left and the right eye images creates the illusion of depth. The memory is used as a buffer to temporarily store the left eye image and the right eye image. The anaglyph generator then fetches the left eye image and the right eye image from the memory in response to the sync signal, for producing a filtered left image and a filtered right image. In this way, each filtered image is respectively tinted with one of the complementary colors. By viewing through a pair of anaglyph glasses, the filtered left and the filtered right images can thus create perception of depth.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in which like references denote similar elements, and in which:

FIG. 1 is a block diagram illustrating a preferred embodiment in accordance with the present invention;

FIG. 2 is a block diagram illustrating an expanded view of the anaglyph generator;

FIG. 3 is a functional illustration of an alternative embodiment for the anaglyph generator;

FIG. 4 is a functional illustration of a bit-block transfer operation performed by an adder in the anaglyph generator; and

FIG. 5 is a flow chart of the alternative embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As illustrated in FIG. 1, a graphics display device 10 of a personal computer provides video signals 132 to a monitor 20. Graphics display device 10 includes a graphics processor 100, a memory 110, a memory controller 120, and a digital-to-analog converter (DAC) 130. According to the present invention, graphics processor 100 further comprises a 3D graphics engine 102 and an anaglyph generator 104. 3D graphics engine 102 and anaglyph generator 104 both access memory 110 by way of memory controller 120. 3D graphics engine 102, for example, receives graphic data and commands from CPU via PCI or AGP bus 140. In normal operation, 3D graphics engine 102 renders a series of 3D animations by calculating the graphic data. Each 3D image in the series of animations is pre-stored in memory 110 to maximize computing power of 3D graphics engine 102. Graphics processor 100 continuously fetches the pre-stored digital images and transmits them to DAC 130. In order to display the transmission on monitor 20, DAC 130 converts the digital images to analog video signals 132. In addition to rendering the 3D animations, 3D graphics engine 102 also calculates one horizontal offset for each one of 3D graphic animations if the stereo function of

-4-

graphics processor 100 is activated. Further, 3D graphic engine 102 provides a sync signal 106 and generates a left eye image 112 and a right eye image 114 in accordance with the horizontal offset, in which the horizontal offset between the left and the right eye images provides illusion of depth. The left eye image 112 and the right eye image 114 are stored in memory 110 for the following operation. Because the left and right eye images generated from the previous operation are buffered in memory 110, 3D graphics engine 102 is available to perform the next operation to maximize the resource of 3D graphics engine 102. For the reasons explained above, the apparatus disclosed in present invention can achieve production of real-time anaglyphs.

With continued reference to FIG.1, anaglyph generator 104 fetches left eye image 112 and right eye image 114 from the memory 110 in response to sync signal 106 to produce a filtered left image and a filtered right image respectively. As such, the filtered left image is tinted with one color and the filtered right image is tinted with another color, wherein these two colors are complementary colors. Anaglyph generator 104, in accordance with sync signal 106, alternately outputs the filtered left and right images to DAC 130. By converting digital signals into analog video signals 132, the filtered left and right images are displayed on monitor 20. A viewer wearing a pair of anaglyph glasses 30 views the images through lenses of matching colors, and one eye sees one image while the other eye sees the other image, thus giving the appearance of depth.

With reference to FIG. 2, a preferred embodiment of anaglyph generator 104 will become more apparent from the following detailed description. When processing color images using computers, it is common to separate an image into primary colors, e.g., red (R), green (G) and blue (B) components. Primary colors are basic colors that can be mixed together to produce other colors. In FIG. 2, anaglyph generator 104 comprises three multiplexers, 220a, 220b and 220c. Each multiplexer is responsible for filtering one color component of an image respectively. Multiplexers 220a, 220b and 220c have substantially the same arrangement. For example, zero (0) is applied to one input port 222a of multiplexer 220a and red (R) component of an image is applied to the other input port 224a of multiplexer 220a. Output port 226a of multiplexer 220a provides output to a filtered image as its the reds in accordance with a stereo enable signal 210 and a control signal C_R. Stereo signal 210 and stereo signal 210 control signal C_R are respectively applied to input terminals 232a and 234a of a logic gate 230a. As shown in FIG. 2, anaglyph generator 104 is enabled to produce the filtered left image and the filtered right image if the stereo enable signal 210 is asserted.

In one embodiment, multiplexer 220a filters out the reds from the left eye image when control signal C_R is deasserted, and admits reds from the right eye image when control signal C_R is asserted. Multiplexer 220b filters out the greens from the right eye image when control signal C_G is deasserted, and admits greens from the left

eye image when control signal C_G is asserted. Likewise, multiplexer 220c filters out the blues from the right eye image when control signal C_B is deasserted, and admits blues from the left eye image when control signal C_B is asserted. As a result, anaglyph generator 104 separately produces a filtered left image tinted blue-green and a filtered right image tinted red. After that, the filtered left and right images are alternately displayed on monitor 20 at a rate of about 60 images/second for each eye. A viewer is provided with a pair of glasses 30 to view the filtered images through lenses of matching colors. In this manner, the observer sees only the blue-green tinted image with the blue-green lens, and only the red tinted image with the red lens, thus providing separate images to each eye.

In another embodiment, multiplexer 220a filters out the reds from the right eye image when control signal C_R is deasserted, and admits reds from the left eye image when control signal C_R is asserted. Multiplexer 220b filters out the greens from the left eye image when control signal C_G is deasserted, and admits greens from the right eye image when control signal C_G is asserted. Similarly, multiplexer 220c filters out the blues from the right eye image when control signal C_B is deasserted, and admits blues from the left eye image when control signal C_B is asserted. Consequently, anaglyph generator 104 separately produces a filtered left image tinted red-blue and a filtered right image tinted green separately. Then, the filtered left and right images are alternately displayed on monitor 20 at a rate of about 60

-7-

images/second for each eye. A viewer wearing a pair of glasses 30 views the filtered images through lenses of matching colors. In this way, the observer sees only the red-blue tinted image with the red-blue lens, and only the green tinted image with the green lens, thus providing separate images to each eye.

FIG. 3 is a functional illustration of an alternative embodiment for the anaglyph generator 104. To achieve a stereo image consisting of two separate images of the same element in two different colors but horizontally shifted, as depicted, anaglyph generator 104 may comprise an adder 320 and a multiplier 310. With reference to a flow chart as illustrated in FIG. 5, the alternative embodiment of anaglyph generator 104 will become clearer from the following detailed description. If the stereo function of graphics processor 100 is disabled (step 500), as described above, graphics processor 100 renders normal 3D animations (step 505) and displays them on monitor 20 by way of DAC 130 (step 515). If the stereo function of graphics processor 100 is enabled (step 500), a horizontal offset is calculated by 3D graphics engine 102 in graphics processor 100 (step 510). 3D graphics engine 102 then renders a left eye image 112 and a right eye image 114, in which some or all elements of left eye image 112 are horizontally shifted in the degree of horizontal offset relative to the same elements of right eye image 114 (step 520). Thereafter, anaglyph generator 104 employs multiplier 310 to multiply left eye image 112 by a first mask 312 and to multiply right eye image 114 by a second mask 314, for separately producing a filtered left image 322 and a filtered right image 324 (step 530).

To produce the stereo image 330, adder 320 manipulates filtered left image 322 and filtered right image 324 to be superimposed on each other (step 540), as depicted in FIG. 3. Then, stereo image 330 consisting of two separate tinted images is displayed in monitor 20 at a rate of about 30 images/second for both eyes. In one embodiment, multiplier 310 blocks the reds of left eye image 112 by first mask 312 to produce blue-green tinted image 322, and blocks the blues and greens of right eye image 114 by second mask 314 to produce red tinted image 324. A viewer is provided with a pair of glasses 30 to view the stereo image 330 through lenses of matching colors. In this manner, the observer sees only the blue-green tinted image with the blue-green lens, and only the red tinted image with the red lens, thus providing separate images to each eye. Because the same elements of the two separate images are shifted horizontally, the observer perceives illusion of depth. In another embodiment, multiplier 310 blocks the greens of left eye image 112 by first mask 312 to produce red-blue tinted image 322, and blocks the reds and blues of right eye image 114 by second mask 314 to produce green tinted image 324. A viewer sees only the red-blue tinted image with the red-blue lens, and only the green tinted image with the green lens, thus providing separate images to each eye. Because the same elements of the two separate images are shifted horizontally, the observer perceives illusion of depth.

Further, adder 320 performs a bit-block transfer operation (B_{OP}) used in computer graphics techniques. B_{OP} is a technique for moving or superimposing pixel blocks

in a source image onto a destination image as shown in FIG. 4, and is more efficient than moving or superimposing individual bits or bytes.

Accordingly, an apparatus for producing a real-time anaglyph has been disclosed. It will be apparent that the invention is not limited thereto, and that many modifications and additions may be made within the scope of the invention. Therefore, it is the object of the appended claims to cover all such variations and modifications as come within the true spirit and scope of the invention.